Comment on "First Observation of Ion Acoustic Waves Produced by the Langmuir Decay Instability"

In a recent Letter by Depierreux *et al.* [1], it was clearly shown that driven levels of ion acoustic waves (IAW) are observed which correlate with stimulated Raman scattering (SRS), and the driven IAW are by-products of the Langmuir decay instability (LDI). However, the authors incorrectly conclude evidence for LDI cascade based on the Thomson scattered spectra of forward propagating and backward propagating IAW. The point of this Comment is to show that the IAW spectra shown in Ref. [1] could be the result of either strong turbulence due to Langmuir collapse or multiple LDI cascades in an inhomogeneous plasma. The IAW spectra in Ref. [1] do not definitively demonstrate LDI cascade.

It is important to understand whether LDI is in a weakly turbulent regime (cascade), or in a strongly turbulent regime due to Langmuir collapse since the saturation behavior of SRS will scale differently with local laser and plasma conditions for these regimes [2]. Indeed, resolving the k-spectrum structure would uniquely determine the turbulence regime, but is an experimental challenge as shown below.

From LDI kinematics using fluid dispersion relations for the electron plasma waves (EPW) and IAW, the wave-number difference between the SRS daughter wave k_{EPW1} and the LDI wave k_{EPW2} is $\Delta k_{EPW}\lambda_D = (2/3)(c_s/v_e)$, where λ_D is the electron Debye length, c_s is the IAW sound speed, and v_e is the electron thermal speed. Each additional step in the LDI cascade also produces a wave-number shift of $\Delta k_{EPW}\lambda_D$. As an example, consider the IAW wave numbers from the first four steps of the LDI cascade process, k_{IAW2}, k_{IAW3}, k_{IAW4}, and k_{IAW5}, where $k_{IAW}^{n+1} = 2k_{EPW}^n - \Delta k_{EPW}$ for the nth cascade step. The two forward propagating waves, k_{IAW2} and k_{IAW4}, have a wave-number difference $\Delta k_{IAW}\lambda_D = (8/3)(c_s/v_e)$, which is the same for the two backward propagating IAW, k_{IAW3} and k_{IAW5}. Using typical values obtained from Ref. [1] for $c_s = 1.8 \times 10^7$ cm/s ($\lambda_S = 4.1$ Å separation between IAW peaks) and $v_e = 1.1 \times 10^9$ cm/s (700 eV), then $\Delta k_{IAW}\lambda_D \approx 0.044$. For the conditions given in Ref. [1], we estimate $\Delta k_{IAW} \approx 2.1 \times 10^4$ cm^{-1}, and $\Delta\omega_{IAW} = \Delta k_{IAW}c_s \approx 3.8 \times 10^{11}$ rad/s. The wavelength separation of the Thomson scattered light between k_{IAW2} and k_{IAW4} (forward propagating IAW) would be $\Delta\lambda/(\lambda_S/2) = \Delta\omega_{IAW}/\omega_{IAW}$, or $\Delta\lambda \approx 0.25$ Å. This is also the wavelength separation between two backward propagating IAW, k_{IAW3} and k_{IAW5}.

The spectral resolution of the scattered light from IAW [1] is ~ 0.2 Å, which would marginally resolve two or more forward or backward propagating IAW cascade peaks. However, the spectral width of each IAW peak is quite broad (~ 1 Å), as seen in Fig. 2a of Ref. [1], and could contain multiple cascade peaks, since they would each be separated by only ~ 0.25 Å. No distinguishable

fine spectral structure is observed on this scale. As noted in Ref. [2], strong turbulence arising from Langmuir collapse produces a broad k spectrum in both the forward and backward propagating directions with respect to k_{EPW1}. This would give rise to broad upshifted and downshifted IAW peaks, as observed in Ref. [1], and the spectral width of each peak would be determined by the angular range of the Thomson probe and collection optics. The angular range discussed in Ref. [1] is sufficient to observe at least the first four IAW from LDI cascade.

Another possible explanation for the IAW spectra in Ref. [1] is that, if LDI were indeed in a cascade regime, then plasma inhomogeneity could blur any fine structure in the IAW spectra. Using the IAW dispersion relation $\omega_{IAW} = k_{IAW}c_s + \vec{k}_{IAW} \cdot \vec{u}$, where u is the flow velocity, and the separation between IAW LDI cascades $\Delta k_{IAW}\lambda_D$, it can be easily shown that a plasma inhomogeneity of $\Delta u/c_S \approx (1/2)\Delta\omega_{IAW}/\omega_{IAW} \approx 0.05$ over the probe volume is sufficient to blur the fine spectral structure from the LDI cascade in the IAW spectrum. Figure 2a of Ref. [1] shows a Doppler shift between the IAW spectra at the two different locations, from which an estimate for the flow gradient of $\Delta u \sim (1/2)c_s$ in 160 μm is obtained. The extent of the collection volume in the flow direction would therefore need to be $\ll 16$ μm so that the LDI cascade structure could be resolved at that location. Additionally, the SRS process itself is believed to create flow inhomogeneity due to momentum deposition of the EPW in individual laser hot spots [3], and can lead to large $\Delta u/c_s$ for moderate SRS reflectivity levels.

In summary, the impressive experimental results obtained in Ref. [1] clearly demonstrate LDI-driven IAW associated with SRS. The IAW spectra, however, do not conclusively support the case for LDI cascade. The IAW spectra are consistent either with strong turbulence due to Langmuir collapse or with multiple LDI cascades in an inhomogeneous plasma, either of which would produce the broad IAW peaks observed in Ref. [1].

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